SHIMMER: Innovative Technology Enabling Unprecedented Science

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Introduction: On March 9, 2007, the first ultraviolet spectrometer using the innovative optical technique known as spatial heterodyne spectroscopy was launched into low Earth orbit from Cape Canaveral, FL. The Spatial Heterodyne Imager for Mesospheric Radicals (SHIMMER) is a deskjet printer–sized rugged spectrometer designed to measure solar resonance fluorescence of hydroxyl (OH) in the Earth's middle atmosphere between 30 and 100 km altitude. It is optimized for high spectral resolution, low mass, low power, low volume, and high sensitivity with no moving parts. SHIMMER is performing as expected and has already returned several hundred thousand atmospheric OH measurements. SHIMMER also detects mesospheric clouds (MCs) at their equatorward edge region, around 55° latitude, where they are believed to be most sensitive to mesospheric change. SHIMMER's unprecedented local time coverage allows the investigation of how atmospheric dynamics influence MCs and their environment and thus potentially bias the interpretation of multi-decadal cloud frequency and brightness trends. To date, SHIMMER data have already led to three significant science results, discussed briefly here.

Mesospheric Clouds Show a Systematic Daily Variation: Historically, satellite measurements of MCs were conducted almost entirely from sun-synchronous orbits at fixed local times. The SHIMMER orbit precession of about 30 minutes per day allows us to investigate the local time dependence of MCs for the first time from a satellite. Figure 6 shows the variation of the seasonally adjusted MC frequency throughout the day, revealing a strong semi-diurnal signature.[1] The dynamic range of this signature is unexpectedly large and will help to reconcile existing satellite data sets that consist of observations at discrete local times.

Discrepancies in the Expected Diurnal Variation of OH: Unlike with mesospheric clouds, we already knew that OH has a diurnal variation. This is because it is produced by the photodissociation of water molecules, and the photodissociation varies with the rising and setting of the sun. The surprise has been the large discrepancy with standard model results. Figure 7 shows the diurnal variation of OH as measured by SHIMMER, compared to model calculations. At 74 km, the agreement is excellent. However, at 80 km, the model underpredicts the observations in the a.m. hours and overpredicts in the p.m. hours. Good agreement is obtained at 1300 local time (LT), which is when we normalize our model to coincident H_2O observations from the NASA/AURA satellite. This discrepancy may therefore suggest a hitherto unknown diurnal variation in H_2O at 80 km. However, the required H_2O variation would have to be very large—possibly implausibly so. Much more work is required to document this discrepancy on a global and seasonal basis before we can begin to solve this puzzle.

Unusual SHIMMER Cloud Observation Consistent with Navy Weather Model: Figure 8 shows a hindcast of the water vapor saturation for June 13, 2007, from a new version of the Navy Operational Global Atmospheric Prediction System (NOGAPS). This version is called ALPHA (Advanced Level Physics High Altitude) and it is a research model that is specifically configured to provide meteorological analyses up to 100 km. The map shows an area of super-saturation ($S > 1$) protruding below 50° N where MCs are rarely seen. Within this super-saturated region the formation, growth, and presence of MC particles is possible. Since MCs are seen only sporadically at mid-latitudes, they attract much attention because this region is much more populated than the polar region and the MCs can be viewed with the unaided eye just after sunset or before sunrise. That the SHIMMER MC sightings on this day show a striking correlation with NOGAPS-ALPHA suggests that we can finally place the occurrence of these previously mysterious events on a firm meteorological footing, perhaps even to forecast them much as tropospheric clouds are forecast.[2]

Acknowledgments: The success of the SHIMMER mission was made possible in part by the dedicated efforts of R. Feldman, J.F. Moser, W.L. Marlin, A. Straatveit, Andrew Kochenash, and the teams at the DoD Space Test Program and AeroAstro Inc.

[Sponsored by ONR, the DoD Space Test Program, and NASA]

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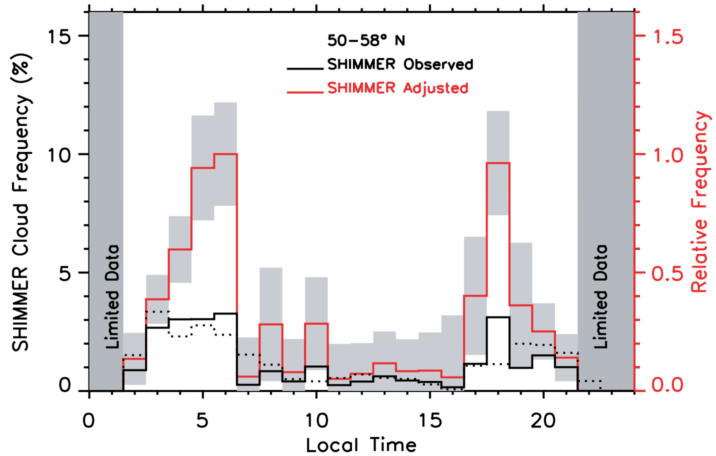

FIGURE 6
The observed (black) and seasonally adjusted (red) diurnal variation of mesospheric clouds as determined from SHIMMER data in the northern summer of 2007. A strong quasi diurnal signature is evident.

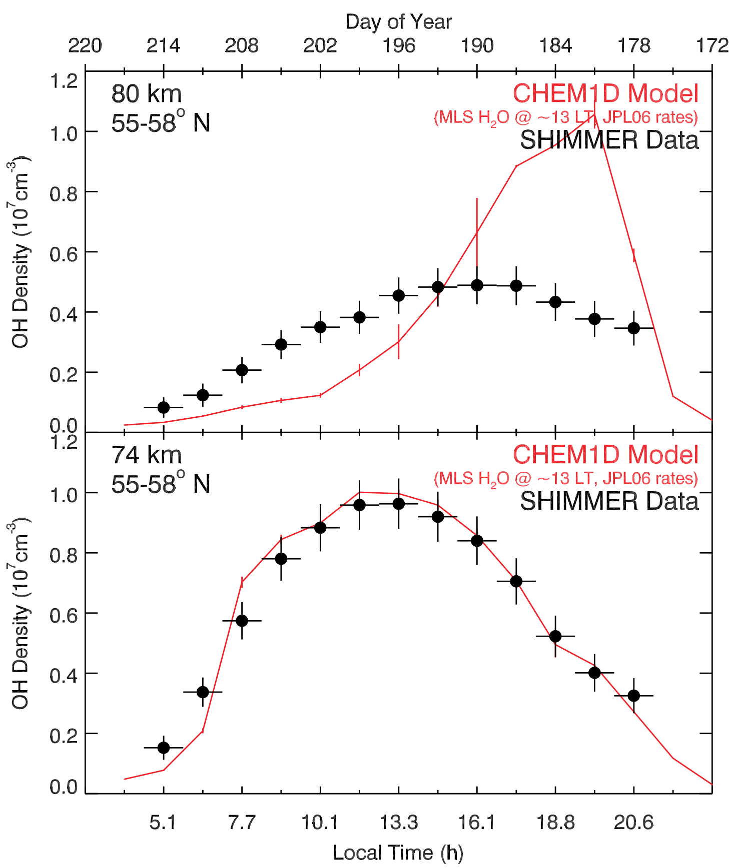

FIGURE 7
The diurnal variation of OH as observed by SHIMMER compared with photochemical model predictions. At 74 km the agreement is excellent; however, the large difference at 80 km indicates an additional, not yet identified, mechanism that is not included in the model.

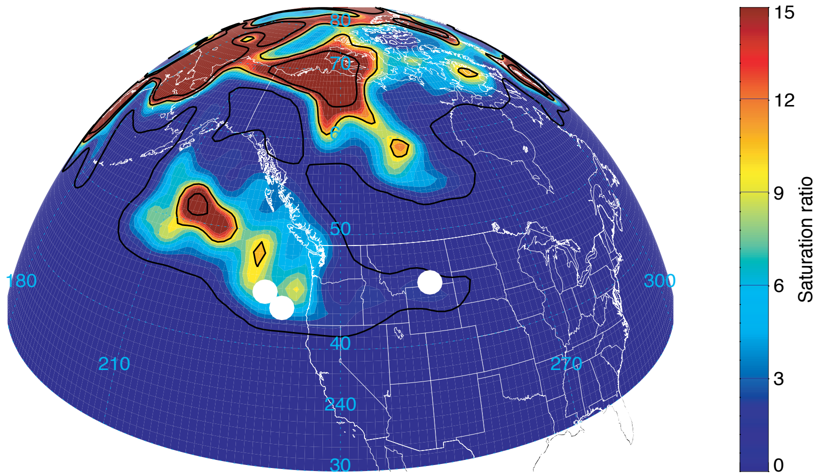

FIGURE 8
This false-color map shows the water vapor saturation hindcast using NOGAPS-ALPHA for 6 p.m. (GMT) on June 13, 2007. The map indicates a supersaturated (S >1) region protruding to lower latitudes (<50° N) where mesospheric clouds are rarely seen. The white filled circles mark the mid-latitude cloud detections of SHIMMER for the same day, which show a striking correlation with the NOGAPS-ALPHA result.